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Worldwide Report

NUCLEAR DEVELOPMENT AND PROLIFERATION

(FOUO 6/82)

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ARGENTINA

CASTRO MADERO ON POSSIBLE USE OF NUCLEAR WEAPONS

PY251849 Buenos Aires DYN in Spanish 1554 in Spanish 25 May 82

[Text] Buenos Aires, 25 May (DYN)--Vice Adm Carlos Castro Madero, chairman of the National Atomic Energy Commission [CNEA], stated today that the rumor that Great Britain will use nuclear weapons in the conflict with Argentina is part of British psychological warfare.

In remarks made on the program "Magdalena and the News" on radio continental, Castro Madero stated that he sent a note to the International Atomic Energy Agency [IAEA] denouncing the possible presence of "nuclear elements" on board British ships in the South Atlantic.

"I have received a reply from the representatives of the member-states and of the governor representing Great Britain in which they emphatically state that it would be totally unthinkable for Great Britain to use nuclear weapons against Argentina," he added.

Castro Madero stated: "There is a world commitment in this regard and if this commitment is not honored, then I would say that we are on the verge of World War III, which I do not believe that the great powers will allow."

In answer to a question, the CNEA chairman confirmed that the Versailles Treaty, signed after World War I [as received], prohibited the use of chemical weapons forever.

He added: "That this conflict--which is limited to two countries--cannot reach the point of using nuclear weapons by the power that has them against another country that does not have them."

Castro Madero added: "In my opinion, it would seem that authorization has been given to resist an air attack, and this definitely gets my attention."

"It gets my attention because a nuclear weapon is not the most appropriate for attacks which are generally carried out unilaterally. It would really make no sense," he added.

In answer to another question, he pointed out that "unless a total war comes, as happened during the late war, the typical atomic attack would be made with small bombs of weak destructive power."

As for the danger of radiation, he stated that "the authorization to use those weapons applies if the fleet is seriously threatened, but I have the impression that it refers to a massive attack by the air force."

"I feel that it is totally impracticable. In the case of the submarine, we, the navy, were very concerned when the "General Belgrano" was sunk, and the investigating committee carried out an analysis of the survivors and verified that it was not a nuclear charge that sank the ship," Castro Madero concluded.

CSO: 5100/2174

CZECHOSLOVAKIA

FAST BREEDER REACTORS, NUCLEAR POWER DISCUSSED

Prague JADERNA ENERGIE in Czech No 1, 1982 pp 2-7

[Article by Vaclav Stach, Institute of Nuclear Research, Rez: "Fast Breeder Reactors and Nuclear Power Production"]

[Text] In connection with the startup of the Soviet BN-600 station, which marks the beginning of commercial operation of fast breeder reactors, this article presents current information on the main characteristics of the sodium-cooled fast breeder reactor as a power source. A brief description of the state of development of these systems in the leading countries is given, and work done in the field by Czechoslovakia is described.

Introduction

Nuclear power stations are now operating in 23 countries, and their net electrical output is 126 GW. An additional 234 power units with a total capacity of 213 GW are under construction [1]. Nuclear energy can directly replace liquid and gaseous fuels for the production of electricity, and for many countries which lack both high-quality fuels and coal it promises a considerable lessening of dependence on import [2].

In this century, most nuclear power units will be light water reactors (PWR [pressurized water reactors], VVER [vater-cooled, water-moderated power reactors], BWR [boiling water reactors]), including graphite-water systems (LWGR [light water graphite-moderated reactor], Soviet designation RBMK), with a certain number of heavy water reactors (Candu or HWR). These reactor types of reactors have better characteristics and capabilities than fossil-fired units of the same capacity. For example, according to the most recent annual report of EdF [French nuclear power office; expansion unknown], in 1979 the specific power production cost in nuclear power stations with PWR reactors (900 MWe) was 0.0868 francs/kWh, compared with 0.1286 francs/kWh in coal-fired stations and 0.1536 francs/kWh in oil-fired stations [3].

In connection with the increasing role of nuclear power in the energy economies of the developed countries, the questions of long-term fuel availability for existing types of nuclear power stations and the limits on their use resulting from the size of natural reserves of nuclear fuel materials are coming to the fore.

According to discussions held by the 8th INFCE [International Nuclear Fuel Cycle Evaluation] working group [4], the net integral consumption of natural uranium by a 1,000-MWe generating unit with a light water reactor over a 30-year period with 70 percent utilization of nominal power output and an enrichment residue of 0.2 percent is 2,730-4,220 tons, depending on the fuel cycle (closed or open). Hence, used in this fashion, 1 ton of natural uranium is the energy equivalent of 15 to 23 tons of standard fuel. According to estimates by the joint NEA-OECD and MAAE working group made at the end of 1977 [5], as of 1 January 1977 proven reserves of economically recoverable uranium in the nonsocialist countries amounted to 2,191 Mt [megatons] and additional assumed reserves to 2,096 Mt, for a total of 4,287 Mt. With the equivalence figure given above, the energy content of these reserves is equal to that of 64 to 99 billion tons of standard fuel, which is less than the 150 billion tons of standard fuel which reference 6, for example, cites for proven world petroleum reserves (in the nonsocialist countries).

Naturally, estimates of world uranium reserves are changing. Large areas have not yet been explored in detail. According to reference 7, detailed evaluations of reserves in the United States had been made by 1980, focusing primarily in medium-grade ores; we may assume that they gave positive results, in view of the recently published U.S. government regulations on nuclear power production (involving a moratorium on the reprocessing of spent fuel). A new report of the joint NEA-MAAE working group at the end of 1979 [8] cites a figure for proven reserves in the basic price category 12 percent higher than that given in the preceding report, as a result of new finds in Brazil and Canada and reevaluation of reserves in the Central African Republic, Namibia, South Africa, Spain and the United States. But even if reserves prove to be several times today's estimates, at current rates of energy consumption the energy potential is on the same order as that of probable world petroleum reserves [6].

Thus uranium reserves are adequate for the immediate needs of nuclear power development, but only their much more intensive use offers a long-term solution. Since these reserves are unevenly distributed through the world, the question of more intensive use is of varying importance in different countries. But the basic trend is the same everywhere. The bulk of nuclear engineering research and development in the industrially developed countries involves breeder reactors.

The Beginning of Commercial Operation of Fast Breeder Reactors

On 8 April 1980 a 600-MW generator unit with a fast breeder reactor went into operation in the Beloyarsk Nuclear Power Station imeni I. V. Kurchatov. The output of this unit, with the type designation BN-600, was smoothly increased in succeeding months, until in September it reached 80 percent of rated output, which was the technical maximum for the so-called "startup configuration" of the cure. This third unit of the Beloyarsk power station has become a reliable generating unit in the Urals electrification system.

The successful operation of the BN-600 unit marks the beginning of commercial operation of fast breeder reactors, which will make possible maximum utilization of the energy potential of natural nuclear fuel sources and will solve the basic fuel and energy problem for hundreds of years to come. Construction of the BN-600 was an extremely important step forward for Soviet science and engineering marked out by the 25th CPSU Congress and made more specific by L. I. Brezhnev at the November 1979 session of the CPSU Central Committee: "Our long-range planning must provide for extensive construction of nuclear power stations with fast-neutron reactors." [9]

The BN-600 is the most powerful fast breeder reactor in the world. Following its construction the Soviet Union is preparing to build similar units with capacities of 800 and 1,600 MW; the details of this construction are expected to be decided in the near future. Of the capitalist countries, France is now reaching the commercial stage with the construction of a 1,200 MW station with a fast breeder reactor in cooperation with Italy and West Germany; startup is planned for 1983 [10].

The current beginning of commercial operation of breeder reactors is a logical result of world technical development to date, which can be broken down into important periods each about a decade long.

The 1950's saw research on the physical principles of reactors and the construction and operation of zero-power or low-power research reactors. The 1960's involved the development of the sodium technology and the construction and operation of pilot reactors with heat outputs in the tens of megawatts, followed by extensive fuel development. In the 1970's demonstration stations with electrical outputs of 250 to 350 MW were completed and put into operation. These were followed in the 1980's by commercial units, opening the way to series construction in the next decade.

The construction of commercial breeder reactors in various countries is affected by other factors in addition to the aspects of world development described above. These involve primarily the degree of planned management of nuclear power development, the size of the role to be assigned to nuclear power in these countries in relation to accessible uranium reserves, and in some cases an initial delay in the breeder programs. As a result of these factors, the United Kingdom has put off for several years the beginning of construction of the CDFR (Commercial Demonstration Fast Reactor) with an electrical output of 1,250 MW; it is not clear whether the United States will build its demonstration station; and stations in West Germany and Japan are to be finished in 1985 and 1987 respectively (the SNR, with a capacity of 300 MWe and the Monju station with a capacity of 250 MWe) [1].

Characteristics of Fast Breeder Reactors

The fundamental and well-known characteristic of breeder reactors is the fact that they reproduce nuclear fuel, which is of fundamental importance for the use of natural nuclear fuel sources for power production. With the limited nuclear fuel conversion capabilities offered by thermal reactors, the theoretical limit of their fuel base is 1 to 2 percent of available uranium reserves. With the reproduction of fuel in breeder reactors there is no such theoretical limit, and the full amount is usable.

In practice this means that breeder reactors can obtain 60 to 70 times more energy from a given quantity of uranium than thermal reactors can. Thus breeder reactors allow more intensive development of nuclear power production without significantly increasing the need for extraction of nuclear fuel materials, with the consequences that attend every extractive activity. This adds to the effective usable reserves of these materials ores of much lower grade. According to reference 5, attention has recently been turned to deposits with average uranium contents of 0.01 to 0.1 percent, which will expand known reserves. A uranium concentration of 0.01 percent means extraction of 10 tons of ore per kilogram of uranium, so that terms of the energy equivalent of uranium in light water reactors given above 1 ton of ore is equivalent to 1.5 to 2.3 tons of standard fuel. With such an equivalence figure, nuclear fuel loses its character as a concentrated natural energy source. The economic consequences for its price, including further complex processing, are considerable. But this situation disappears if we multiply the energy equivalent by 60 to 70, as is the case with breeder reactors.

Another important source of energy for fast breeder reactors is impoverished uranium, which is a waste product from the enrichment of uranium for thermal reactors. The production of 1 kg of uranium at 3 percent enrichment, which is the value used in pressurized water reactors, produces a waste of 4.5 to 5.5 kg of impoverished uranium (residue from the enrichment process). This material is useless for thermal reactors, but if it is used as a fuel for breeder reactors, according to reference 10 a ton of the impoverished uranium is equivalent to 1 Mt of standard fuel. On the basis of the projected fuel regime for VVER reactors we may estimated that 30 years' operation of a set of power stations with reactors of this type having a total capacity of 10 GW will produce 35 kt of impoverished uranium. This quantity, used in fast breeder reactors, is the energy equivalent of 35 Gt of standard fuel, or 350 times the current primary consumption in Czechoslovakia (100 Mt of standard fuel per year). According to reference 15, the 20 kt of impoverished uranium already accumulated in Great Britain would, if used in fast breeder reactors, be equivalent to 40 Gt of coal, which is 400 years' output at current rates in the UK.

Thus there is a practically unlimited supply of fuel for nuclear power production with breeder reactors. Accordingly their importance in the history of power production is so revolutionary that it generally makes people think that this stage is extremely far off and not currently practicable. But with the current advent of commercial breeder reactors it is possible to evaluate their other positive basic characteristics, which do not call forth such ideas.

First, they are capable of competing economically with other types of power stations. This is of course assumed by their investors. Data on unit investment expenditures have already been supported by experience with the construction of units on a commercial scale, while data on fuel expenditures are supported by experience with semi-full scale operation. Even though extrapolating from these prototypes to the characteristics of a series-constructed station is a considerable step, the degree of uncertainty has been narrowed. According to reference 11, the specific operating expenditures of the Phenix demonstration plant (operation and fuel) are now considerably lower than the price per kilowatt-hour at fossil-fired stations. Investment costs for the first Superphenix station are high (5.35 billion francs without fuel), but the cost per kilowatt-hour of the station will probably be very close to that for conventional power stations meeting modern air purity standards. With subsequent commercial stations the price per kilowatt-hour is likely to be competitive with light water stations in France. More precise data in terms of 1979 prices are given by reference 15. According to this reference, the investment expenditure on the Superphenix station is 7,900 francs/kW, compared with 3,445 francs/kW for a PWR with a unit output of 1,300 MWe. It is expected that this cost will decrease by about one-fourth in subsequent 1,500-MWe units. The production cost for the Superphenix stations is expected to be 0.24 francs/kWh, while that for subsequent breeder units is expected to be 0.16 francs/kWh, compared with 0.2 francs/kWh for coal-fired stations and 0.12 francs/kWh for PWR's (the latter two data obviously come from other sources than reference 3).

Nuclear power stations with sodium-cooled breeder reactors, particularly with an integrated primary circuit, have a number of inherent qualities which make for safe operation with minimal undesirable effects on the surroundings. They include:

--a practically pressure-free primary circuit in which a sudden disruption of integrity of any size is extremely improbable, and even if it did occur, could be dealt with decisively and without difficulty by built-in protective vessels;

--a considerable margin between the nominal sodium output temperature and the boiling temperature of sodium, which may be considered the point at which the integrity of the fuel element surface, as the primary barrier to fission products, is threatened;

--enclosure of the primary-circuit sodium in a single vessel of simple shape: if the integrity of this vessel is breached the protective vessel assures reactor safety and removal of excess heat by normal means;

--the possibility of cooling the core for reactor shutdown by natural convection, with sufficient thermal capacity that the operator has time, in case of a breakdown of the main heat removal and automatic control systems, to put backup system into operation.

--reactor dynamic characteristics which cause "slow" station behavior, as confirmed by all operators of demonstration prototypes, which makes control easier, and in the hypothetical case of a breakdown in the automatic systems allows deliberate manual control intervention and the like; the term "walk-away safety" is used figuratively to indicate that if the operator left the plant it would remain in a safe state.

In order for permission for their construction and operation to be granted, the stations had to meet safety criteria and requirements similar to those currently applying to thermal reactors; they are universally recognized as being at least as safe as the latter. As regards the radiation situation in the facility and the surroundings, the measured radioactivity and exposure values are far below the values prescribed by standards. The radiation load on the surroundings will be smaller than that for current thermal reactors. Reference 15 gives the following ranking in terms of radioactive emissions [in ascending order]: oil-fired power stations, fast breeder reactors, pressurized water reactors, coal-fired stations. The Superphenix station is 45 kilometers from Lyon, with a population in the millions. The thermal load on the surroundings is considerably lower as a result of the units' much higher thermal efficiency: for the same electrical power, the quantity of heat liberated to the surroundings is a quarter to a third less.

Reprocessing of Irradiated Fuel

The use of breeder reactors involves the reprocessing of irradiated nuclear fuel. Effective breeder characteristics are obtained with a uranium-plutonium fuel cycle based on a plutonium charge and an external cycle. In the future the production of these charges will be the objective, or rather the result, of the operation of a set of such reactors, which will constitute a self-developing system whose dynamics are characterized by the "doubling time." During the beginning of commercial operation of breeder reactors (and for a rather long time) the source of plutonium will be spent fuel from thermal reactors, as a result of both the large group of already-completed thermal reactors and the breeders' great plutonium-generating capability. The requirements regarding reactor fuel cycle characteristics based on minimizing the doubling time are currently meaningless; the reprocessing of irradiated fuel from breeder reactors will be rather similar to the reprocessing of fuel from thermal reactors.

But the necessity of reprocessing irradiated nuclear fuel does not apply only to the use of fast breeder reactors: it is also a precondition of all other possibilities for fundamentally increasing the energy utilization of natural nuclear fuel reserves in a power production. The known facts in this area (see e.g. reference 12) have recently been reviewed as part of INFCE activities organized with the cooperation with MAAE. The conclusions of INFCE working group No 8, whose task was both to examine the question of how to make the best use of uranium in current thermal reactors and to evaluate the thorium cycle, were that "Realistically, the possible saving of uranium in the open fuel cycle is not particularly large and is only a fraction of the saving possible in the closed fuel cycle. Nor would a changeover to the thorium cycle produce a fundamental improvement in the open cycle. A radical decrease in uranium consumption can be achieved only by means of the closed fuel cycle" [4].

Logical Aspects of Nuclear Power Production with Fast Breeder Reactors

Nuclear power production with fast breeder reactors is based on the abundant reserves of energy contained in the nonfissile (fertile) isotopes ^{238}U and ^{232}Th in locations whose exploitation to supply thermal reactors would probably not be considered, but which would be extracted for use in breeders, and in materials which are already associated with, and already, of course, "consumed" in, the "thermal" stage of nuclear power production. With a ton of nonfissile isotope being equivalent to a million tons of standard fuel, these reserves are inexhaustible from the viewpoint of current power production.

Some years ago, A. Weinberg gave a succinct description of the use of these isotopes in fast breeder reactors as catalytic combustion, with the plutonium charge functioning as catalyst. With a breeding ratio considerably greater than unity an excess of catalyst (plutonium) is created, making it possible to expand the process. Depending on specific conditions, it is also possible to extract plutonium from the process and use it in another area.

From this follows the dual function of breeder reactors for the "thermal" stage of nuclear power production. The first aspect is conservation of natural fuel reserves. To the extent that we replace thermal reactors with breeder reactors, we prolong the lifetime of the former. The second function is that of replenishing the stock of fissile materials, or, in the figurative terms just mentioned, of replenishing the catalyst which is consumed in combustion of nonfissile isotopes in thermal reactors.

In the combination, or rather in the effectively managed symbiosis, of breeder and thermal reactors we may find a solution to the problem of nuclear power's increasing role in meeting the needs of society.

Breeder Programs in the Leading Countries

Even at the beginning of nuclear power, the Soviet Union devoted special attention to fast breeder reactors because of their promising capabilities, and thus far the Soviet breeder reactor program has set the pace worldwide. The BN-350 demonstration plant in Shevchenko began producing power a year before the French Phenix and 4 years before the British PFR [1], and it has the highest output of these first prototypes. It was supplanted in first place as regards output by the BN-600 unit, the starting point for commercial construction. L. I. Brezhnev's report to the 26th CPSU Congress mapped out the task of "faster development of nuclear power, including breeder reactors," [16] and the Document "Guidelines for the Economic and Social Development of the Soviet Union" adopted by the 26th CPSU Congress sets the task of "developing new designs for 800- to 1,600-MW power units using fast breeder reactors" [17].

In France the commercial reactor program stems from the Superphenix station, which is in the final stage of construction and is to go into operation in 1983. Construction of two units of the Superphenix II type, with an electrical output of 1,600 MW, is to be begun at approximately the same time; these are to be completed in 1988 and 1989, so that by 1990 France will have an installed fast breeder reactor station capacity of 4,400 MW. In the next decade construction is likely to continue at a fairly rapid pace; according to current forecasts, at least an additional 12,000 MW of capacity is to be put into operation between 1990 and 2000, so that by the year 2000 breeder reactors will account for 20 percent of installed nuclear capacity; as early as 1991-1995 new construction of stations using PWR reactors is expected to decrease.

The investor for the Superphenix stations is the joint economic consortium NERSA, of which the French EdF has a 51-percent share, the Italian ENEA [expansion unknown] a 33-percent share and the West German-Belgian-Dutch-British SBK (Schneller Brueter Kernkraftgesellschaft [Fast Breeder Company]) consortium a 16-percent share [10]. The Italian share is represented by a suitable volume of equipment deliveries (including reactor parts); the participation of all the non-French organizations is motivated by access to technology and information.

The mirror image arrangement, i.e. 51 percent SBK, 33 percent ENEL and 16 percent EdF, is proposed for construction of the West German SNR-2 commercial prototype, which will be based on technology developed in the De-benelux program (West Germany, Belgium, Holland) and tested in the NSR-300 demonstration station. This program is lagging behind the French program because of a later beginning and slower pace; the NSR-300 station in Kalkar, West Germany is in the initial stage of construction and is expected to go into operation in 1985. The design for the SNR-2 prototype is currently being refined and the prospects for further construction are not yet fixed. The technical delay in the De-benelux program is expected to be compensated by cooperation with the United States and particularly by participation of the UK, the country with the longest breeder program in Western Europe.

The British program suffers from slippage in the construction of the PFR demonstration station, which was put into operation only in 1977. In addition the design prepared for the CFR commercial prototype (now the CDFR) underwent a number of modifications and no decision has yet been made on the beginning of construction. The main reason is an overall dampening of the conception of nuclear power's role in the UK, which in the last decade has dropped from the world's largest producer of electricity from nuclear power to sixth place.

A late beginning has also affected the situation in Japan, where the breeder program is now proceeding rapidly. The constructon of the Monju demonstration plant is to begin next year, with completion in 1987.

The breeder program in the United States has taken its own course. After the failure with the Enrico Fermi station, whose construction was begun in 1956, at the same time as the first light water prototypes (Dresden-1, Indian Point-1) and which broke down in 1966 before being brought up to nominal power, the U.S. program has remained in the research and development stage. The total expenditure is already many billions of dollars ($500 million was allocated for 1980), and it is considered to be the largest technical development program in any country's history [13].

This position does not seem particularly stable, and fundamental changes in the near future are not ruled out. The main argument for the decisions taken in the past has been world uranium resources, which will suffice to supply expected development of nuclear power through the year 2000 based on light water reactors with an open fuel cycle. The arguments against it focus on technical obsolescence and loss of technical and commercial position on foreign markets. There have been reports of preparations for licensing negotiations between the leading U.S. reactor producers and the French.

The Situation in Czechoslovakia

Czechoslovakia is part of CEMA's joint program of breeder reactor development, which is one of the CEMA countries' long-term special cooperative programs in the energy field. The leading country and the one which has dealt with most of the problems of the joint program is the Soviet Union. Czechoslovakia is involved in this work in the areas for which we are well suited and which currently represent the interests of our technical development in accordance with the state technical development plan. The objective is to make the most effective contribution to the joint program while creating the technical preconditions for building breeder reactors in Czechoslovakia with the technical assistance of the Soviet Union, and for the production of certain equipment for these stations in Czechoslovak plants. This is leading to an extremely important, innovative stage in the development of the Czechoslovak nuclear power industry and the development program for nuclear machine-building. The work in these areas is coordinated on a nationwide basis and is focusing on the sodium type of breeder reactor.

The most progress with breeder reactor station equipment has been made in the development of steam generators, which are designed by the Research Institute of Power Production Machinery Plants in Brno in production cooperation with Prvni brnenska strojirna [Brno No 1 Machine Works] National Enterprise. Using design and process principles which were mastered in the design of CO_2-water steam generators for the A-1 station, the concept of a modular sodium-water steam generator with special design of the modules was developed. After a series of successful tests of the components in a sodium test facility at the Research Institute of Nuclear Reactors in Demitrovgrad, USSR, this concept was implemented in a 30-MW steam generator (PG BOR) which was installed in 1973 at the BOR-60 experimental breeder reactor station in Dimitrovgrad. This was followed by development work on a 200-MW steam generator for the BN-350 station, which, together with successful operating tests of the PG BOR, led to commercial delivery of the steam generator with the type designation Nada [Russian "Nadya"] for the Soviet BN-350 breeder demonstration plant in Shevchanko. The Nada steam generator was produced in 1977 and put into permanent operation in the power station in 1980. In addition, another unit of the same type was produced and delivered to the Soviet Union, while pre-contract arrangements for an additional three units of the type are being made, so that in about 1985 the entire BN-350 station will be equipped with steam generators designed and produced in Czechoslovakia. Thus Czechoslovakia has joined the small number of leading countries which produce breeder reactor power station equipment and is the first country in the world to carry out foreign commercial deliveries of such components.

The PG BOR was operated successfully at the Dimitrovgrad station until this year, running at power for a total of 35,000 hours. It demonstrated the merit of the concept not only by its reliable operation in stationary and transient operating states but also by its behavior in regard to a single weld defect which was found during operation, and particularly in a so-called "major emergency experiment" conducted with it. Because of its design, which used a double tube plate, the loss of tightness of a welded joint between a tube and tube plate on the water side, which was discovered after several years' operation, did not lead to a reaction between water and sodium. It was found by the operating detection system, and the generator was repaired in 5 days. In the major emergency experiment, 7 kg of steam was introduced into the liquid sodium in one branch of the steam generator to simulate a major loss of tightness. This did not cause a breach of the steam generator, and accordingly after disassembly of the branch in which the emergency had intentionally been produced and diagnostic testing of the equipment, the steam generator was returned to operation.

At the end of this year [1981] the PG BOR was disassembled to make way for the experimental PG BOR II. This unit incorporates the new concept of "reverse design" (sodium in the tubes and water or steam in the space between them), which is an approach used nowhere else in the world and expands the variety of steam generators developed in Czechoslovakia.

The equipping of the BN-350 station with the Nada steam generator, the successful long-term operation of the PG BOR, followed by the experimental PG BOR II, and the development of steam generators for additional power generating stages of fast breeder stations which is now under way, constitute an important technical basis for future production cooperation by the Czechoslovak nuclear machine building industry in the "breeder" stage of nuclear power production in the socialist community.

Sigma's Research Institute, in cooperation with the Sigma Modrany National Enterprise, developed bellows-type valves for sodium which had nominal inner diameters from 50 to 150 mm. The prototypes of this series were produced in 1974 to 1975 and underwent detailed tests in Soviet test installations in 1975 to 1976. Design directives and technical specifications for production were issued on the basis of these tests, and in 1979 to 1980 the production of a test series of these valves with optimized design was organized for long-term tests in the Soviet Union. Some prototypes were also installed in test facilities in Czechoslovakia and East Germany to gain further information from long-term operation.

The successful development of the small valves was followed by work on special fast-acting 350-mm diameter sodium fittings designed in accordance with the original sectional concept (instead of the full cross section, four sectors are opened or closed), thus giving the required operating speed. The design and technical development led to the production of two prototypes in 1977, of which one passed demanding tests at a sodium test facility in Slovakia (500 open-close cycles, 5 thermal shock tests) without any effect on its tightness and ability to function; its long-term testing is continuing. The other prototype was subjected to tensometric measurements and hydraulic tests at the Sigma Lutin National Enterprise. On the basis of the tests, experience with production of prototypes, and research work, an optimized design of the 350 mm fitting was developed. The prototype RCA-350 was awarded a gold medal at an international mechanical engineering exhibition in Brno in 1977.

Bellows-type sodium valves and the RCA-350 will be part of the set of fittings in higher-power breeder reactors for power production; the design of other special components of this system is under way. In addition, successful development work has now created the technical preconditions for extensive future production cooperation in this area.

In cooperation with the Research Institute of Ferrous Metallurgy and a number of other research and production organizations, a design material has been developed for the components described. Austenitic steels were checked for the required properties under operating conditions in order to evaluate the metallurgical processes used to produce them. A ferritic low-chromium steel stabilized with niobium has been developed for the heat exchange tubing of steam generators and the Vitkovice o.p. [sectorial enterprise] has mastered its production. Process development conducted under operating conditions has made it possible to replace import of design materials (which was never undertaken) for the second PG BOR II by domestic production organized as a scientific and technical development project. In spite of inherent shortcomings and complications, this material was made available and the production of the PG BOR II was carried out under these conditions. This was a valuable large-scale technological experiment, with the task of developing construction materials; it yielded knowledge for the formulation of guidance technologies for steel and pipe production.

The participation of Czechoslovak organizations in the CEMA joint program for development of breeder reactors for power production, which is led by the USSR, allows us to participate to a certain extent in the solution of key problems in these systems and thus to create the scientific and technical basis for their domestic application. The development of methods and programs for designing physical and physico-technical characteristics of the reactors, the making of energy calculations for the reactor, determining the hydrodynamics and heat engineering characteristics of the fuel systems with regard to reactor safety, and conducting theoretical and experimental investigation of shielding [stineni] involved cooperation and mutual division of labor between the Institute of Nuclear Research and ZES Skoda [? Power Production Equipment Plants]. Problems of technical and radiation safety were allocated between EGU [expansion unknown] and the Institute of Nuclear Research. Thermomechanical and strength problems of steam generators were solved by SVUSS [State Research Institute for Machinery Construction].

A workable basis for these activities is the application of research results in Soviet prototype equipment, which makes it possible to compare computed and laboratory results with the characteristics of the finished component, and with data obtained from critical systems during physical and power-production startup or operation of reactors. This has allowed Czechoslovak organizations to keep pace with the worldwide development of knowledge in regard to certain key breeder reactor problems. The technique of using joint design collectives, with division of labor, joint use of experimental equipment, exchange of computer programs and data, and the processing of results as joint technical reports and recommendations for computations, plans and design work, has justified itself in international cooperation.

Conclusion

As the role of nuclear power in the energy economies of the developed countries increases, the question of providing a long-term fuel supply for nuclear power stations of existing types, against a background of limited natural reserves of nuclear fuel materials, is coming to the fore. Only much more intensive use of nuclear fuels can provide a long-term solution to this problem. The importance of this solution differs in different countries, but the basic tendency is the same everywhere. In all of the developed countries, the bulk of research and development work in nuclear engineering is devoted to breeder reactors.

Successful startup of the BN-600, the third unit at the Beloyarsk power station, marks the beginning of commercial operation of breeder reactors, which, according to long-term plans, will be built on a large scale in the Soviet Union. France is now entering the commercial stage with the construction of the Superphenix station and a predicted more rapid pace of further construction. The situation in order countries is affected by additional factors, particularly inadequate planned management of the development of nuclear power, uncertainty about the size of the role to be allocated to nuclear power in the various countries in connection with available uranium reserves, and finally, in some cases, by initial delays in the breeder program. Accordingly, plans for commercial construction of nuclear power stations with breeder reactors have not yet been finalized in these countries.

The energy contained in the nonfissionable isotopes ^{238}U and ^{232}Th, which are in deposits whose use for supplying thermal nuclear reactors would probably not be considered, but which will be extracted for breeder reactor use, and in materials which have already been involved, and, of course, "consumed" in the "thermal" stage of nuclear power, represents a literally inexhaustible source of energy when used in fast breeder reactors. The results of long-term operation of three demonstration plants and experience with the construction of the first commercial designs proved the additional important positive capabilities of sodium-type breeder reactors; these are, in particular, safety and minimal undesirable effects on the environment. In a number of respects these reactors have shown better characteristics than light water reactors, as well as economic characteristics which make it possible to expect economically acceptable production costs even at current fuel prices, and an even better situation when expected increases in the price of uranium occur.

The involvement of Czechoslovakia in CEMA's multinational program, led by the Soviet Union, allows us to keep pace with worldwide state of the art in research and development and to prepare for the breeder reactor stage in the power and machine building industries.

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